NEPHELIUM LAPPACEUM SEED AS NATURAL COAGULANT/FLOCCULANT FOR LANDFILL LEACHATE TREATMENT

by

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This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

as partial fulfillment of requirements for the degree of

MASTER OF SCIENCE
(ENVIRONMENTAL ENGINEERING)

School of Civil Engineering
Engineering Campus
Universiti Sains Malaysia

July 2017

ACKNOWLEDGEMENTS

In the name of ALLAH, the most merciful and the most gracious. Thank you, ALLAH, for giving me an opportunity to pursue this course and for good health that You give me in order to do this research. This work could not have been possible without following persons and institution that I sincerely acknowledge.

Firstly, I would like to express my highest gratitude to my supervisor, Prof. Dr. Hamidi Abdul Aziz for giving me a chance to conduct this research and for giving me many useful advices and knowledge regarding this field.

I would like to thank all post-graduate students who are also under the same supervisor as mine especially to Puan Farah and Miss Farhana for giving me ideas and advices regarding my projects and thesis writing. Not to forget, undergraduate student, Natasha for always helping me sampling the landfill leachate at APLS.

A special thanks to staffs of School of Civil Engineering, USM; Puan Shamsiah, Encik Mohad, Encik Zaini, dan Encik Nizam for lending me their precious time in order to help me doing this research. I also want to thank my classmates, Aini, Amilin, Zaidin, Izyan, Luqman, Ganga, and Salmah for sharing me knowledge and helping me out with this research.

Last but not least, I want to thank my parents, Encik Rahmat and Puan Zuraidah, for giving me words of wisdom and supporting me whenever I was having a rough time. Without them, this research cannot be realized.

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List of Abbreviations

APLS	Alor Pongsu Landfill Site
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
SS	Suspended Solids
DO	Dissolved Oxygen
FESEM	Field Emission Scanning Electron Microscopy
FTIR	Fourier Transform Infrared Spectroscopy
HDPE	High Density Polyethylene
$SnCl_4$	Tin tetrachloride
SVI	Sludge Volume Index
Vs	Sludge settling velocity
PZC	Point of Zero Charges
MLSS	Mixed Liquor Suspended Solids
NH_3-N	Ammonia-Nitrogen
TDS	Total Dissolved Oxygen
HCl	Hydrochloric Acid

BIJI *NEPHELIUM LAPPACEUM* SEBAGAI BAHAN PENGGUMPAL/PENGELOMPOKAN SEMULA JADI DALAM OLAHAN LARUT LESAPAN

ABSTRAK

Penjanaan larut lesapan di tempat pelupusan sampah telah memberi banyak risiko pencemaran alam sekitar yang ketara kerana kandungannya yang berbahaya dan bertoksik boleh mendatangkan mudarat kepada ekosistem jika terus dilepaskan ke dalam alam sekitar. Bahan penggumpalan dan pengelompokan berasaskan kimia biasa digunakan dalam proses penggumpalan – pengelompokan. Akan tetapi, keburukan penggunaan bahan-bahan kimia telah menyebabkan para penyelidik mencari bahan-bahan semula jadi untuk menggantikan atau mengurangkan jumlah bahan penggumpal dan pengelompokan berasaskan kimia. Biji *Nephelium lappaceum* telah dipilih dalam kajian ini sebagai bahan penggumpal/pengelompok semula jadi untuk mengolah larut lesapan dari tapak pelupusan sampah Alor Pongsu (APLS). Keberkesanan biji *Nephelium lappaceum* ini ditentukan melalui satu siri ujian balang dengan mencari keadaan operasi yang terbaik (pH dan dos) untuk biji *Nephelium lappaceum* dan $SnCl_4$ sebagai bahan penggumpal. Prestasi penggumpalan dan pengelompokan diukur melalui kecekapan penyingkiran warna, pepejal terampai (SS), dan keperluan oksigen kimia (COD). Keputusan menunjukkan biji *Nephelium lappaceum* sebagai bahan penggumpal tunggal boleh menghapuskan 19.48% warna, 35.62% COD, dan 0% SS dalam kondisi yang terbaik iaitu pH 6 dengan dos 2 g/L. Sementara itu, $SnCl_4$ sebagai bahan penggumpal tunggal boleh memberikan peratusan penyingkiran yang tinggi iaitu 98.22% SS, 88.86% warna, dan 84.22% COD pada pH 7 dengan 10.50 g/L $SnCl_4$.

Dengan membandingkan kecekapan penyingkiran oleh kedua-dua bahan penggumpal, biji *Nephelium lappaceum* tidak memberi kesan yang memuaskan, tetapi biji ini menunjukkan prestasi yang sangat baik dalam menghapuskan bahan pencemar sebagai bahan bantuan penggumpalan atau pengelompokan dengan $SnCl_4$ sebagai pengumpalan utama dan justeru dapat mengurangkan kepekatan $SnCl_4$ dari 10.50 g/L ke 8.40 g/L dengan dapat merawat 88.86% SS, 87.57% warna, dan 75.94% COD. Selain itu, keberkesanan biji *Nephelium lappaceum* dapat meningkatkan prestasi enap cemar dan kebolehan enapan. Biji *Nephelium lappaceum* meningkatkan saiz flok dari ketumpatan flok, pengenapan halaju enap cemar dan juga indeks isipadu enap cemar. Kesimpulannya, biji *Nephelium lappaceum* mempunyai potensi untuk digunakan sebagai pengelompokan semula jadi dengan bahan pengumpalan berasaskan kimia untuk mengolah larut lesapan dari tapak pelupusan sampah dan ini boleh mengurangkan penggunaan bahan pengumpalan berasaskan kimia dan meningkatkan prestasi pengenapan enap cemar.

NEPHELIUM LAPPACEUM SEED AS NATURAL COAGULANT/FLOCCULANT IN LANDFILL LEACHATE TREATMENT

ABSTRACT

Landfill leachate produced from landfilling has caused pollution risk to environment due to the harmful and toxic content if directly discharged into environment. Chemical based coagulants and flocculants are commonly used in coagulation – flocculation process. However, the drawbacks of using these chemical materials have triggered researchers to find natural materials to substitute or reduce the amount of chemical based coagulants and flocculants. *Nephelium lappaceum* seed has been chosen in this study as natural coagulant/flocculant to treat landfill leachate from Alor Pongsu Landfill Site (APLS). The effectiveness of the seed was determined through a series of jar tests by finding the best operational conditions (pH and dosages) for *Nephelium lappaceum* seed and $SnCl_4$ as coagulant. The performance of coagulants was measured through the removal efficiencies of colour, suspended solids (SS), and chemical oxygen demand (COD). Results indicated that *Nephelium lappaceum* seed as sole coagulant could remove 19.48% of colour, 35.62% of COD, and 0% of SS at the best conditions which is pH 6 with dosage of 2 g/L. Meanwhile, $SnCl_4$ as sole coagulant could remove high percentage of pollutants which is 98.22% of SS, 88.86% of colour, and 84.22% of COD at pH 7 with 10.50 g/L of $SnCl_4$. *Nephelium lappaceum* seed is not effective as $SnCl_4$ when used as sole coagulant, but it shows excellent performance in removing pollutants as flocculant with $SnCl_4$ as primary coagulant and thus, has accomplished the aim of reducing the amount of $SnCl_4$ from 10.50 g/L to 8.40 g/L with removal efficiencies of 88.86% colour, 87.57% SS, and 75.94% COD. Besides

that, the effectiveness of *Nephelium lappaceum* seed can be further proven with sludge performance and settleability. *Nephelium lappaceum* seed helps in improving the sludge performance and settleability by increasing flocs size, density of flocs, sludge settling velocity as well as sludge volume index. In conclusion, *Nephelium lappaceum* seed has a potential to be used as natural flocculant with chemical based coagulant to treat landfill leachate treatment and this could reduce the usage of chemical based coagulant and improve the sludge settling performance.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Solid waste management has become a major concern in the world, especially in developing countries. This is due to solid waste generation that keeps increasing year by year corresponding to the growth of population, economic prosperity, and rapid urbanization (Ho et al., 2017). It is about 95% of solid waste generated has been dumped in landfill (Bashir et al., 2010). Malaysia highly depends on landfilling as a main waste disposal method due to the simple disposal procedure and low cost as compared to other disposal methods such as incineration and anaerobic waste treatment (Moh and Latifah, 2017) However, this kind of disposal method has led to overflowing of landfill that may pollute the surrounding environment with its toxicity.

Landfill leachate is a complex wastewater generated when water percolates through solid waste at landfill that may contain high concentrations of biodegradable and non – biodegradable organic matters, ammonia nitrogen, phosphate, colour, and suspended solid (Ching et al., 2011). Disposal of raw leachate directly without undergoing any treatment could cause soil, surface and groundwater contamination, which indirectly would affect living organisms, including degeneration of human health. For that reason, Malaysian government has enforced environmental rules and regulations that require landfill leachate to be treated and monitored prior discharge. This was done to prevent contamination of water resources and reduce the harmful impacts of landfill leachate to the environment.

Several treatments that are used to treat wastewater and water have been employed to treat landfill leachate. For instance, biological treatment, chemical treatment, coagulation – flocculation, and reverse osmosis that are commonly used in wastewater treatment have been applied in landfill leachate treatments to minimize the contaminants and reduce the negative impacts on the environment (Aziz et al. 2011). However, some of these treatments are not suitable to be used in certain landfill leachate due to the variability of leachate characteristics. Moreover, landfill age also plays an important role in deciding suitable treatment methods due to the changes of leachate characteristics (Zin et al., 2013). Young landfill leachate releases large amount of volatile fatty acid content and can be characterized by high BOD which is more than 10 g/L and high ratios of BOD/COD (>0.7) (Kurniawan et al., 2006). Therefore, the most suitable treatment to be used for young landfill leachate is biological method due to its high concentration of biodegradable substances in the landfill leachate (Comstock et al., 2010). On the other hand, matured and stabilized landfill leachate has high strength of COD (500 - 4500 mg/L), pH higher than 7.5, and low biodegradability (BOD/COD<0.1) (Bashir et al., 2010). During this phase, chemical and physical treatments are the best methods to be used, as biological treatment is ineffective in removing pollutants.

Coagulation – flocculation process is a typical physico – chemical treatment process that is broadly used in most raw water and industrial wastewater treatment. This process involves the mechanisms of destabilization of colloidal particles by adding coagulants and promoting agglomeration of flocs (Teh et al., 2014). Generally, inorganic coagulants are used in the coagulation – flocculation process, such as alum, polyaluminium chloride (PAC), ferrous sulfate, and ferric chloride (Mojiri et al., 2014). Inorganic metal salts are effective pollutant removal, but due to the increasing

awareness on toxicity from excessive use of inorganic coagulants, there have been many studies conducted to alternatively replace or reduce inorganic coagulants with natural coagulant or flocculant in wastewater treatment (Antov et al., 2012). Nevertheless, these natural coagulants are still not commonly used in landfill leachate treatment even though they are biodegradable, eco-friendly, low in price, as well as abundant in source.

1.2 Problem Statement

Landfill leachate is rich in chemical oxygen demand (COD), colour, suspended solids (SS), and heavy metals (Mojiri et al., 2014). Therefore, landfill leachate needs to be treated before being discharged into the environment. Untreated landfill leachate may deteriorate the quality of receiving water bodies, such as lake, river, and stream, near the landfill sites.

The Malaysian legislation has consented a list of parameters of landfill leachate discharge limit in Environmental Quality (Control of Pollution from Solid Waste Transfer Station and Landfill) Regulations 2009. The concentrations of SS, colour, and COD in landfill leachate are often found to be multiple times higher than the permissible discharge limit (Zakaria et al., 2015). Hence, these parameters need to be lowered within the range of permissible discharge limit before being discharged into the environment.

There are various treatments of landfill leachate, including biological and physico-chemical treatments. Alor Pongsu Landfill Site (APLS) is a mature and stabilize landfill which has no treatment applied on its landfill leachate. Physico-chemical treatment is more suitable to be used in this kind of landfill leachate as it has low BOD content (Ghafari et al., 2010). Coagulation – flocculation is one of the physico-chemical treatment methods that has been used widely in water, wastewater and landfill leachate treatment. Coagulation – flocculation process is commonly practiced using inorganic metal salts as coagulant/flocculant. However, excessive usage of these inorganic metal salts may cause adverse effects to the environment and pose a risk to human health (Renou et al., 2008). Therefore, it is vital to develop and utilize natural coagulants/flocculants for landfill leachate treatment in order to reduce and eliminate the adverse effects to the living organisms and environment.

Malaysia is one of the tropical countries that is rich with various kinds of fruits. Thereby, many food industries take advantage of this richness by producing canned fruits. *Nephelium lappaceum* canning industry is well-established in Malaysia and Thailand, and this industry involves the production of *Nephelium lappaceum* fruits in syrup (Abidin et al., 2014). During the canning process, *Nephelium lappaceum* fruits are deseeded and the seeds are usually disposed, thus becoming wasted by-products. Therefore, utilization of *Nephelium lappaceum* seed is needed in order to improve sustainability of the fruit canning industry waste management, as well as reducing solid waste generation. There was a preliminary study done on *Nephelium lappaceum* seed polysaccharide as natural coagulant in treating turbidity of water (Abidin et al., 2014), but there is no study done to date to test the usage of *Nephelium lappaceum* seed as natural coagulant or flocculant in treating landfill leachate.

Therefore, this leaves a research gap that must be filled, which triggered the interest to study on the effectiveness of *Nephelium lappaceum* seed as coagulant or flocculant in landfill leachate treatment. In this research, the investigation on *Nephelium lappaceum* seed covers the usage of the seed as sole coagulant, and as flocculant with $SnCl_4$ as coagulant to remove SS, colour, and COD from landfill leachate.

1.3 Objectives

This research aims to determine the effectiveness of using *Nephelium lappaceum* seed as coagulant/flocculant in removing colour, suspended solid (SS), and chemical oxygen demand (COD) in landfill leachate treatment. In order to accomplish this, the following objectives are outlined:

1) To investigate the characteristics of *Nephelium lappaceum* seed as coagulant/flocculant in term of pH, particle size, molecular weight, zeta potential, functional groups, surface morphology

2) To determine the best operational conditions (pH and dosage) of *Nephelium lappaceum* seed and $SnCl_4$ as coagulants for treating landfill leachate by evaluating and comparing the performance of the treatment in terms of colour, COD, and SS

3) To investigate the possibility of reducing the quantity of Tin (iv) chloride ($SnCl_4$) as primary coagulant in the presence of *Nephelium lappaceum* seed as flocculant

4) To examine the performance of sludge formed in coagulation – flocculation process by using $SnCl_4$ as coagulant with and without the aid of *Nephelium lappaceum* seed as flocculant at the best operational conditions.

1.4 Scope of Work

The research focuses on determining the efficiency of natural material (*Nephelium lappaceum* seed) as an alternative coagulant or flocculant besides metal salts materials that are currently widely used, such as alum and PAC in landfill leachate treatment. The research was done by conducting laboratory tests to achieve the main research objective. Leachate samples were taken from Alor Pongsu Landfill Site (APLS), which is located in Perak. Characteristics of the leachate samples on their chemical and physical properties were observed for four months, which is from January to April 2017. The effectiveness of coagulant was evaluated through removal of chemical oxygen demand (COD), suspended solids (SS), and colour from landfill leachate. The best operational conditions of coagulation were identified through determination of optimum pH and optimum dosage of both *Nephelium lappaceum* seed and $SnCl_4$. The evaluation was made through jar test operation that mimicked the coagulation process in the treatment plant. The jar test process involved rapid mixing, slow mixing, and settlement with different time limit. These three operations were derived from similar past studies. Sludge formed resulting from the coagulation

process at best operational conditions of two coagulants was evaluated based on sludge settling rate, sludge volume index, functional groups, floc size, density, and surface morphology.

1.5 Dissertation Outline

The dissertation consists of five chapters. Chapter 1 comprise the introduction to this project, which includes background of the present study, problem statement, objectives, and scope of the study. Chapter 2, focuses on literature review, and similar past studies done on topics related to the present study, which include studies and articles on solid waste management in Malaysia, coagulation – flocculation process in treating landfill leachate, and natural coagulants. Chapter 3 stipulates the methodologies used in this research. This chapter describes the details on the research design and procedures of the experiment. Chapter 4 contains comprehensive discoveries, analysis, and results gained from the present study. Elaboration and details on the findings are covered in this chapter as well. The last chapter, which is Chapter 5, presents the overall conclusion to the research findings. It also includes useful and beneficial recommendations for future research work improvement and enhancement.

CHAPTER 2

LITERATURE REVIEW

2.1 Solid waste management

Solid waste management refers to all activities and actions required to manage solid waste from its inception to its final disposal stage including collection, transportation, waste treatment and disposal of solid waste, together with monitoring and regulation of disposal (UNSD, 1997). It also comprises the legal and regulatory framework that relates to solid waste management. Hence, solid waste management is an obligation placed upon everyone in reducing the adverse effects of waste on health, environment, and aesthetic values.

However, solid waste management has become a crucial issue to be solved as the volume of solid waste generated keeps on increasing every year due to many factors in particularly the growth of population and economic activities. The increase in world population causes global urbanization and economic expansion of developing countries, which in turn contributes to the accelerated increase of rate of solid waste production. According to a recent study by World Bank (2012), the global solid waste generation is estimated to be 1.3 billion tonnes per year or an average of 1.2 kg/capital/day.

However, it can be seen that the waste generation rates per capita differ across countries and cities depending on the level of urbanization and economic wealth. For example, developing countries such as North America and European Union produced high generation of solid waste, and it is expected that Asia, Latin America, and South